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# United States Patent [19]

Lin et al.

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[54] **PROCESS OF FABRICATING SEMICONDUCTOR DEVICES HAVING LIGHTLY-DOPED DRAIN**

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### Related U.S. Application Data

[63] Continuation of Ser. No. 237,064, May 3, 1994, abandoned.

[51] Int. Cl.<sup>6</sup> ..... **H01L 21/265**

[52] U.S. Cl. .... **437/43; 437/44; 437/28**

[58] Field of Search ..... **437/44, 43, 28**

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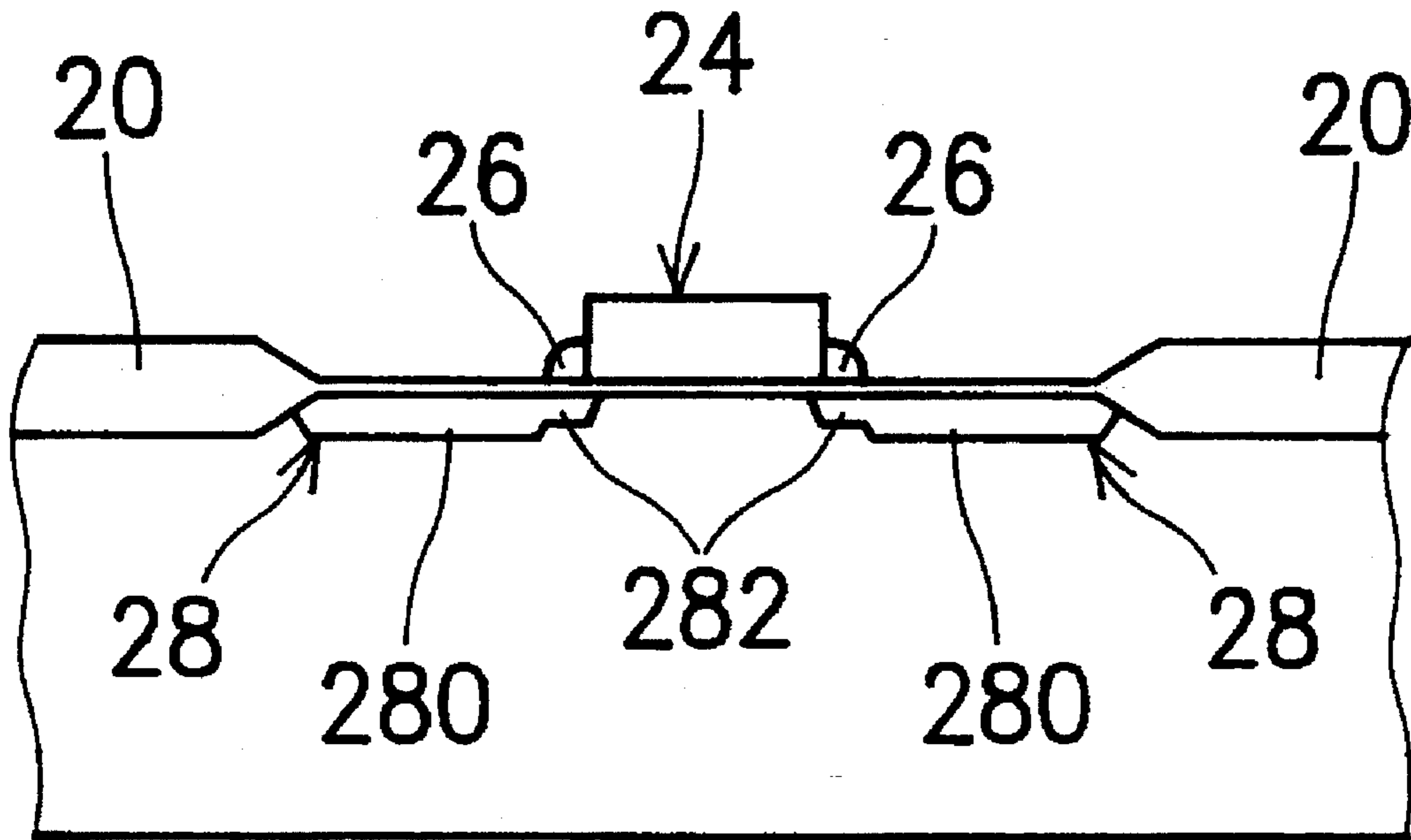
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### [57] ABSTRACT

A process for fabricating semiconductor devices having lightly-doped regions in its drain and/or source. The semiconductor device has a gate structure formed on its substrate, and the sidewalls of the gate structure covered by sidewall spacers. The sidewall spacers having a selected thickness obstructs the impurity implantation and constitutes a lightly-doped region in addition to the relatively heavily-doped regions that are not obstructed during the implantation process. Both the lightly- and heavily-doped regions together constitute the drain and/or source of the semiconductor device.

**9 Claims, 2 Drawing Sheets**



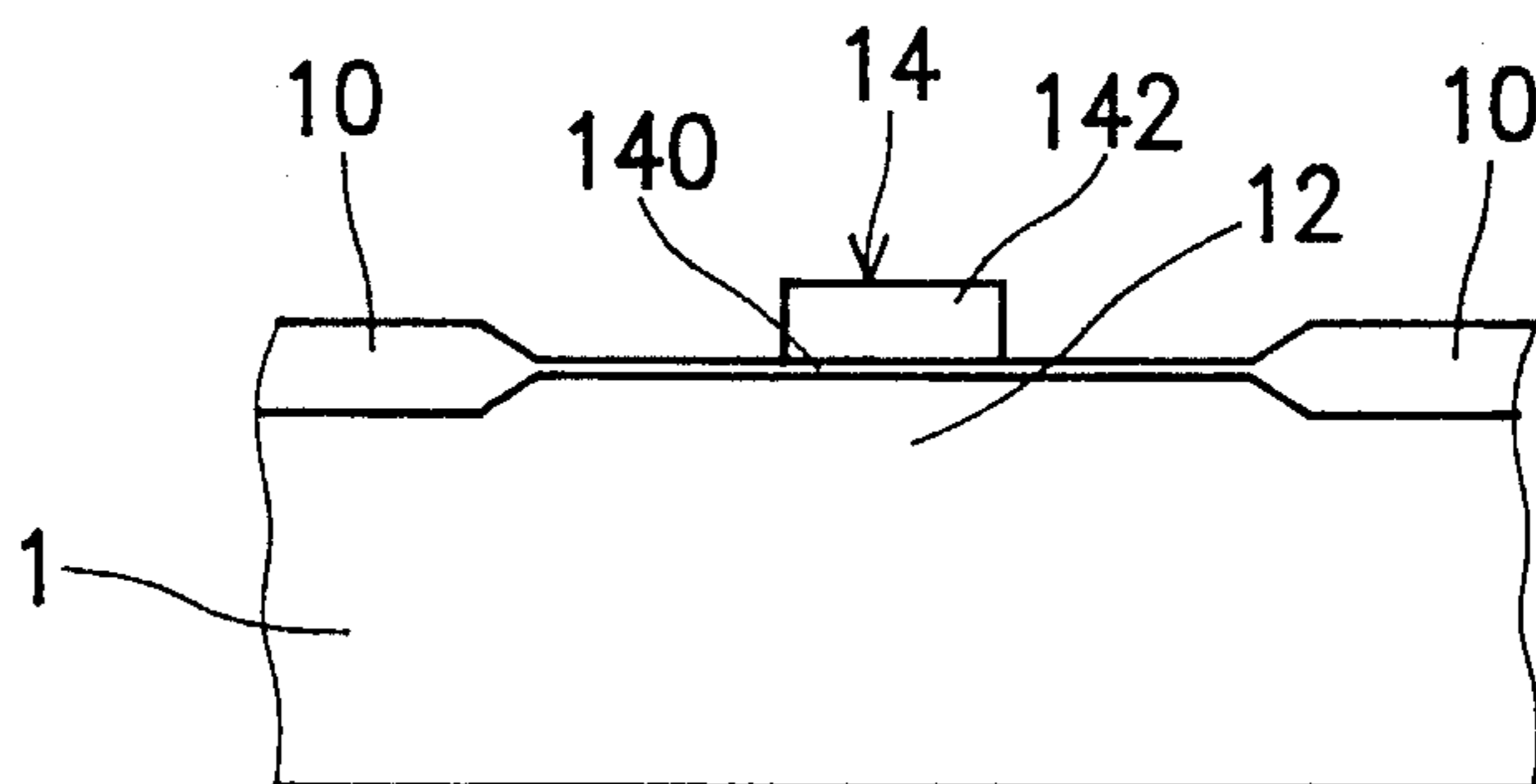


FIG. 1a (PRIOR ART)

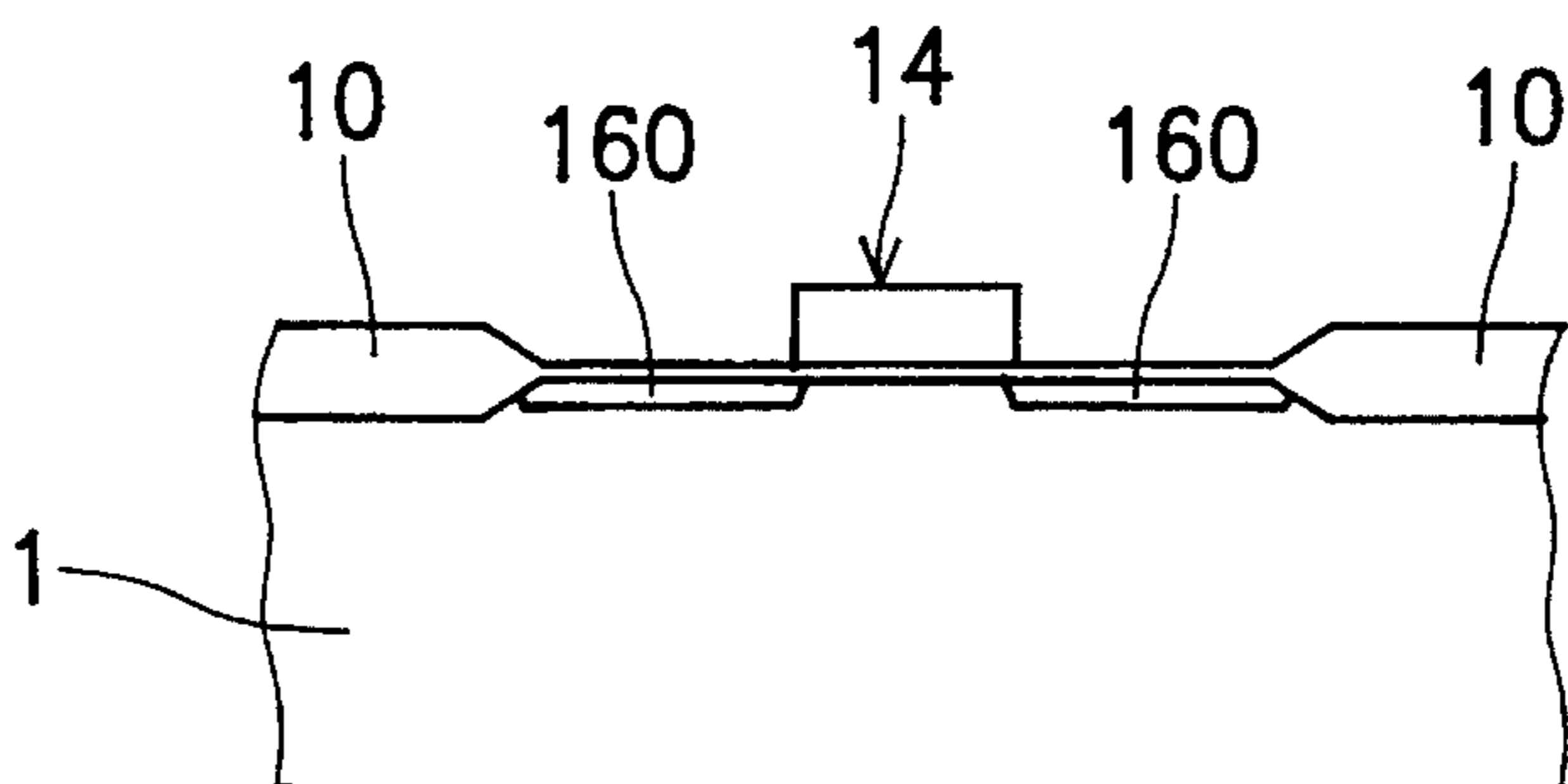


FIG. 1b (PRIOR ART)

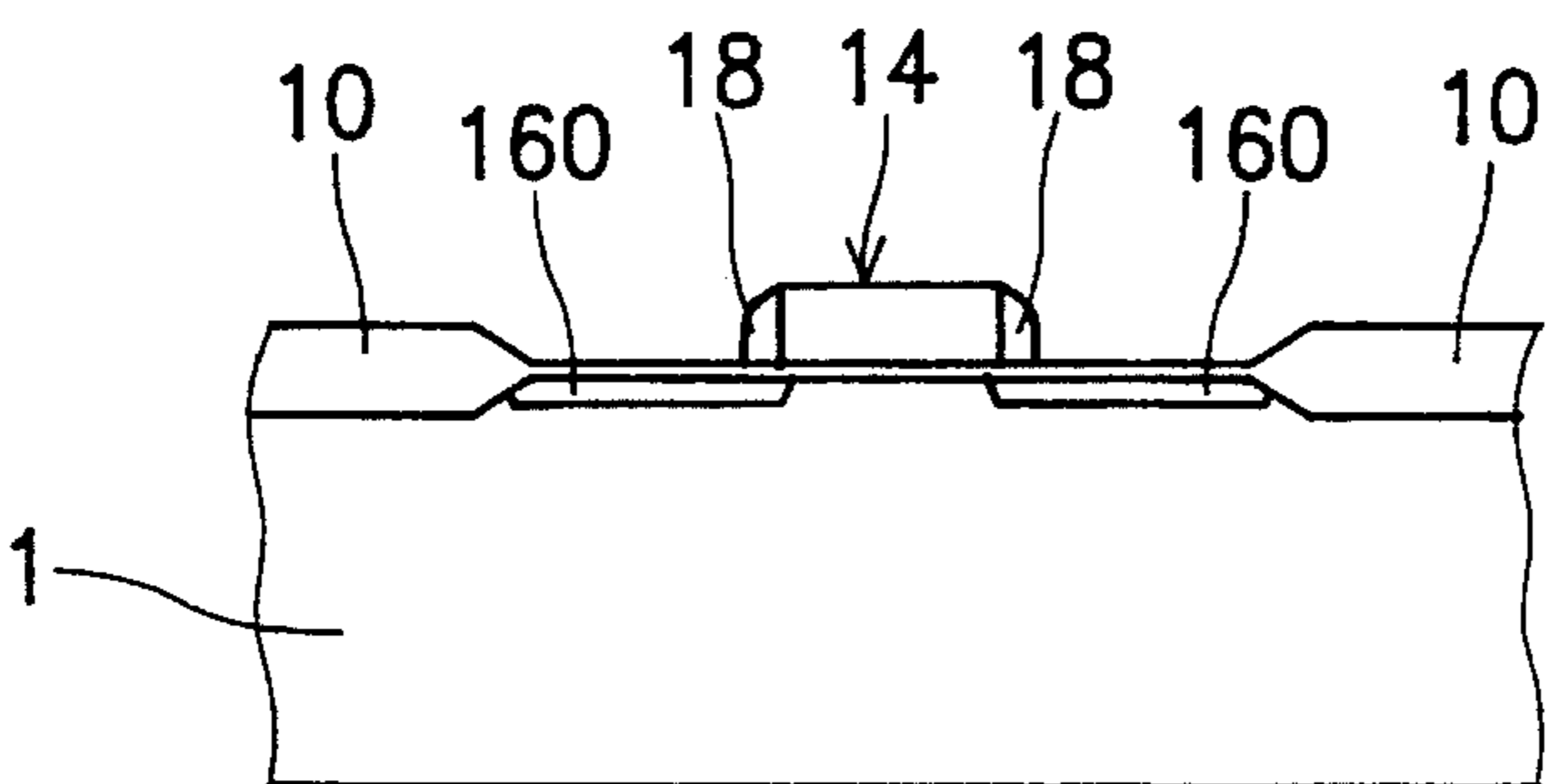


FIG. 1c (PRIOR ART)

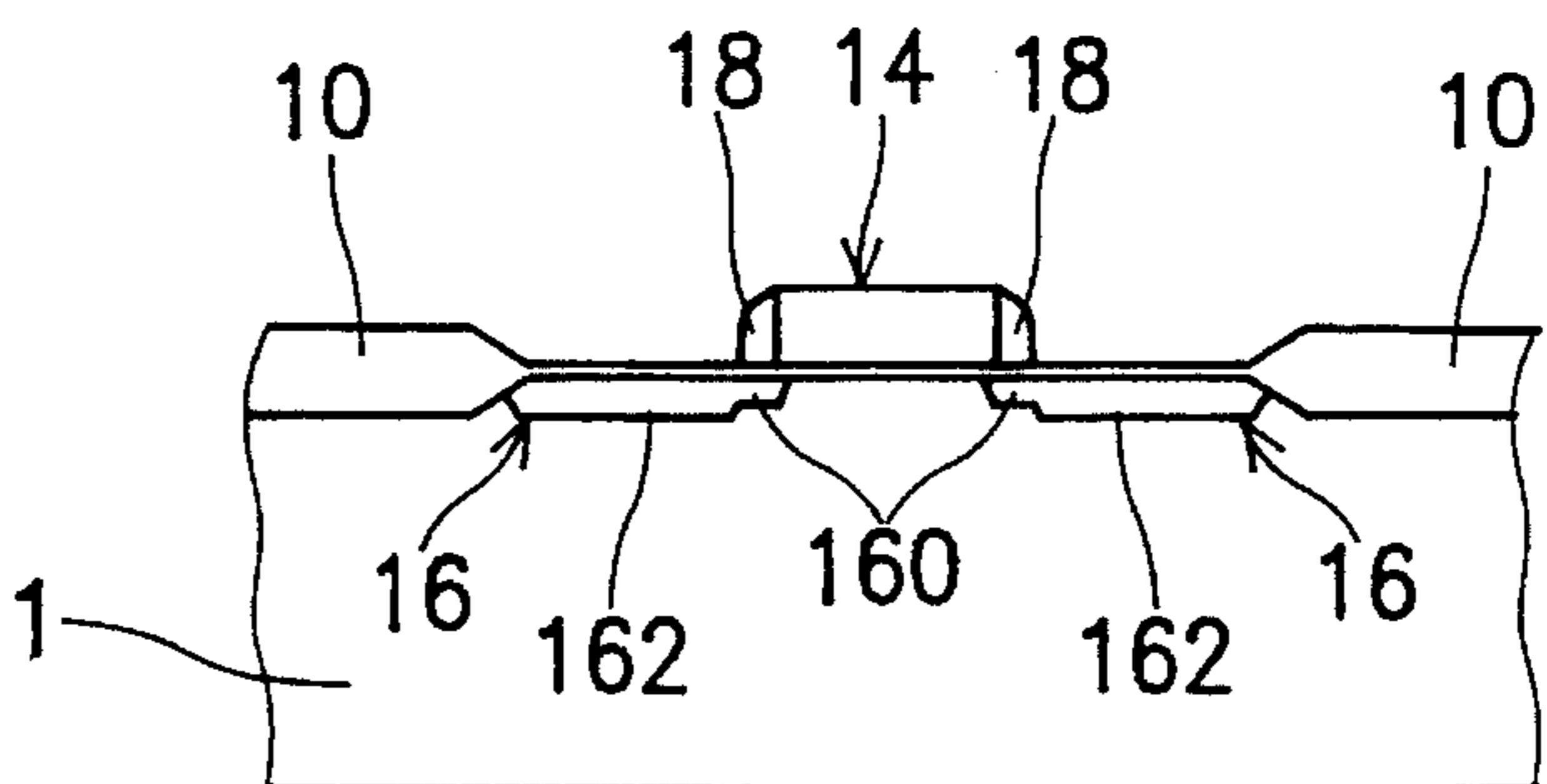


FIG. 1d (PRIOR ART)

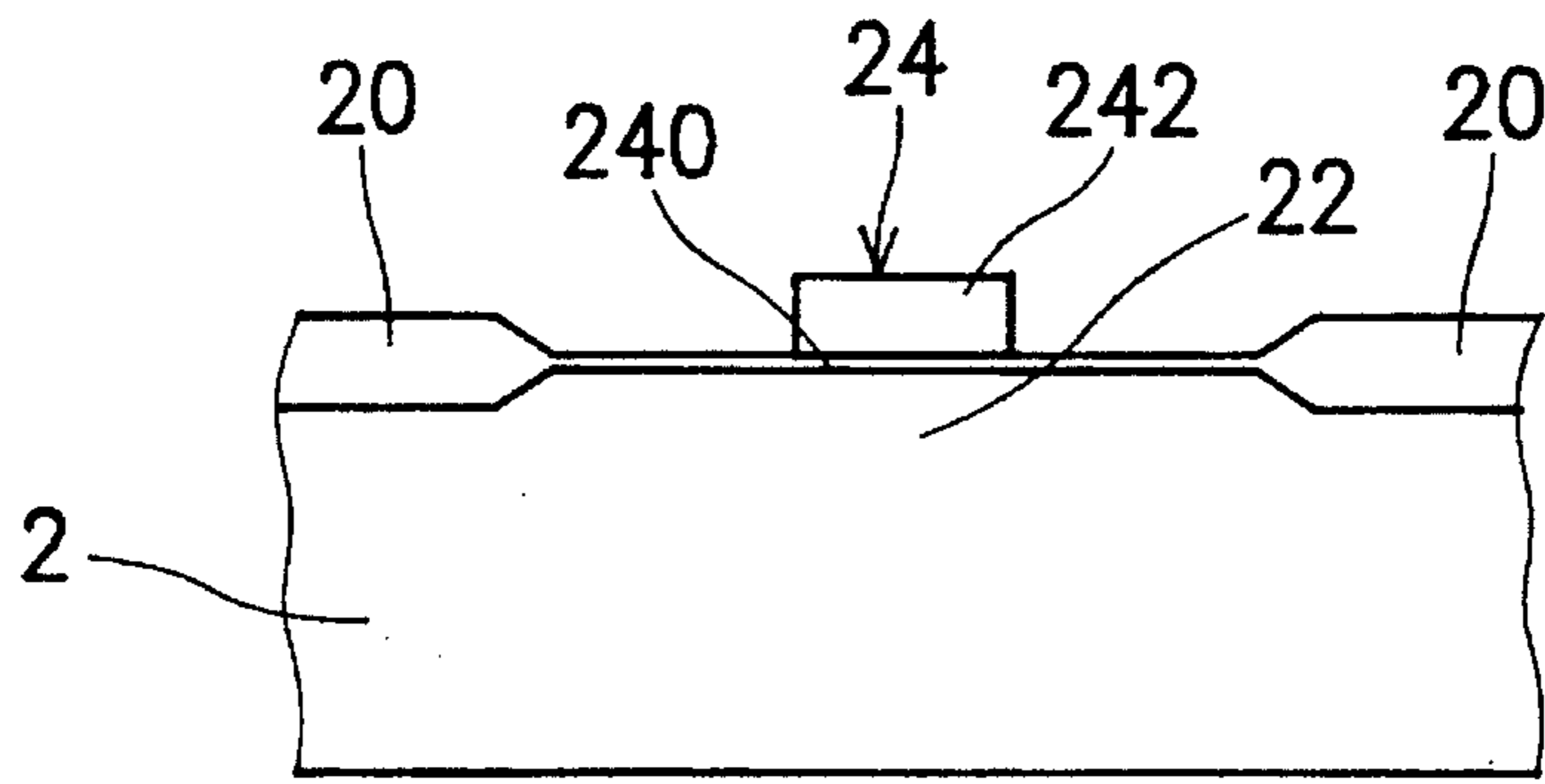


FIG. 2a

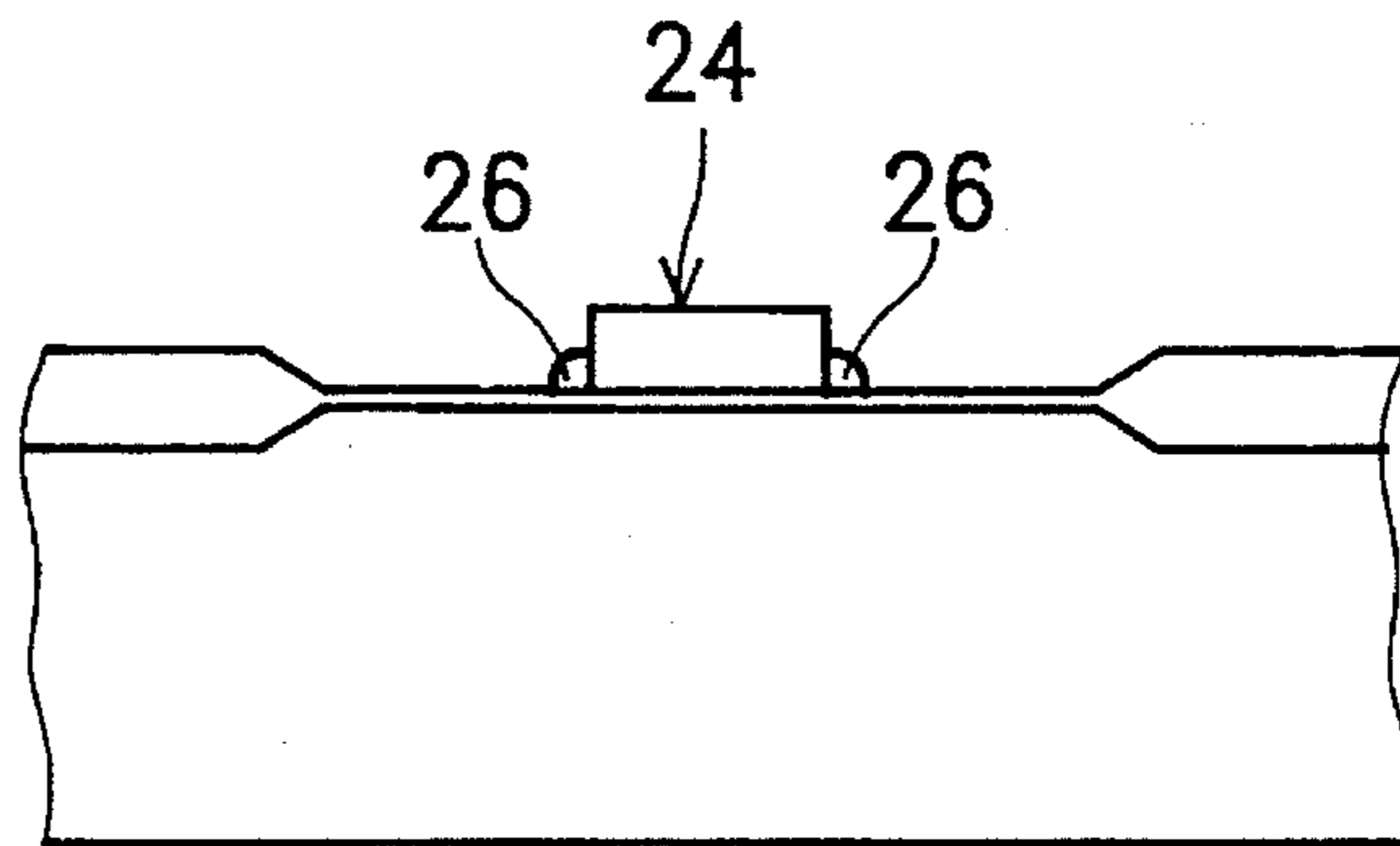


FIG. 2b

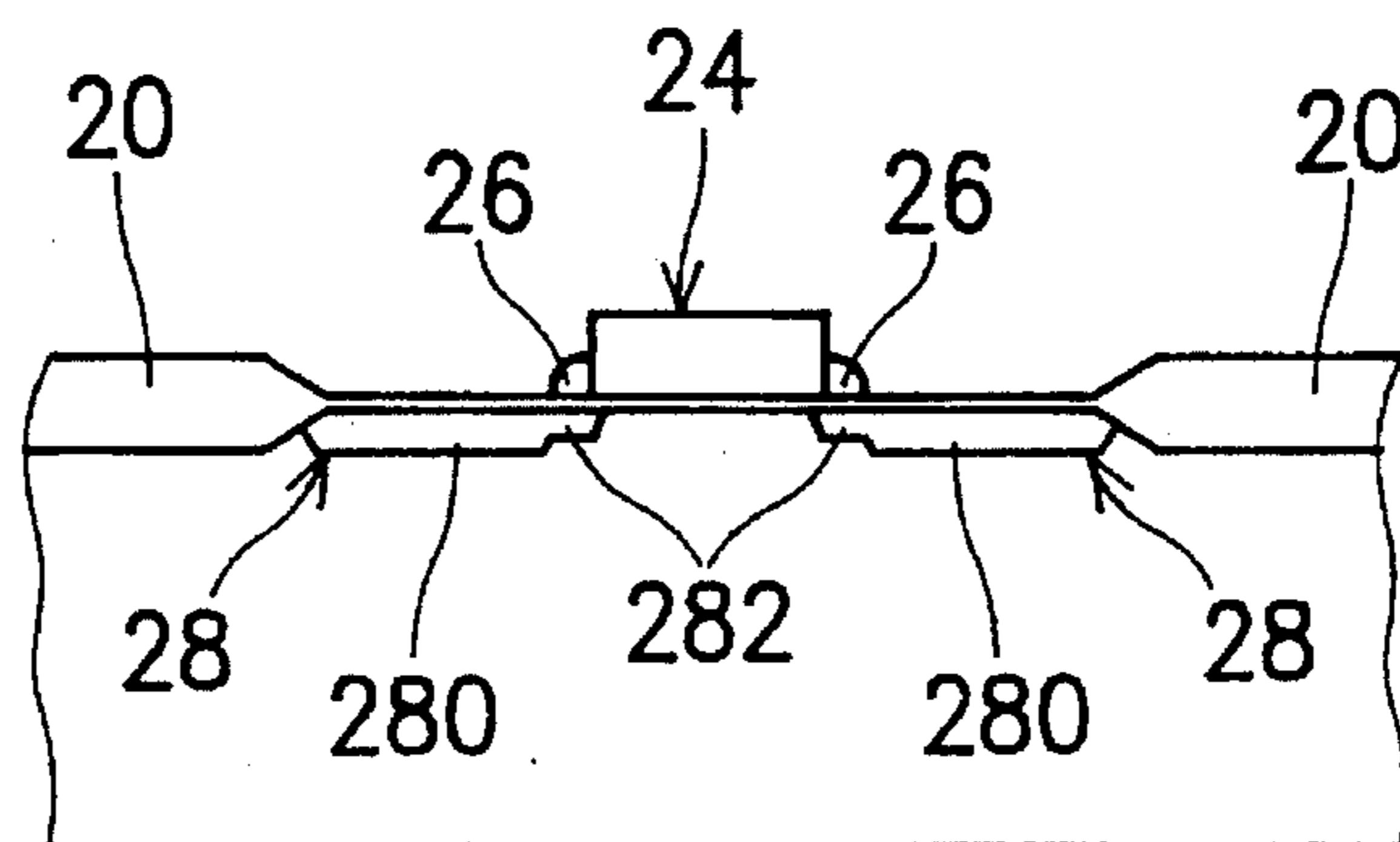


FIG. 2c



## PROCESS OF FABRICATING SEMICONDUCTOR DEVICES HAVING LIGHTLY-DOPED DRAIN

This is a continuation of application Ser. No. 08/237,064  
5 filed May, 3, 1994, now abandoned.

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

This invention relates in general to semiconductor devices  
10 having lightly-doped drain and source. In particular, this  
invention relates to semiconductor devices having drain and  
source with both lightly- and heavily-doped regions. More  
particularly, this invention relates to the process of fabricat-  
ing semiconductor devices by one single implantation pro-  
cedure to obtain devices having drain and source with both  
lightly- and heavily-doped regions.

#### 2. Technical Background

The continuous trend towards the miniaturization of semi-  
conductor devices has driven integrated circuits (ICs) into  
the sub-micron level of device fabrication. Thermal elec-  
trons trapped in the gates of the transistors in an IC device  
can adversely influence the reliability of the device. This  
effect poses a serious problem in the sub-micron category of  
semiconductor devices. A fabrication process for making  
lightly-doped drain and source regions for ICs has been  
25 proposed, such as the process exemplified here that makes  
the device, which is shown in cross sections in its process  
stages as in FIGS. 1a to 1d.

The conventional fabrication process typified in FIGS. 1a  
to 1d depicts, in cross sectional views, a semiconductor IC  
device having lightly-doped drain and source during its  
fabrication process stages. The fabrication can be charac-  
terized in the following stages:

First, as is shown in FIG. 1a, a semiconductor substrate 1  
(of the P or N type) has a Field region OXide layer 10 (FOX)  
formed on its top surface which defines an active region 12.  
A gate oxide layer 140 and polysilicon layer 142 are further  
fabricated on the active region 12 to define a gate 14.

Secondly, as can be seen in FIG. 1b, impurities (N-type  
impurities such as P, or P-type impurities such as B) are  
implanted to form lightly-doped regions 160 (N- or P-im-  
plantation regions). Typically, N-type impurities are  
implanted into a P-type substrate while P-type impurities are  
implanted into a N-type substrate.

Next, FIG. 1c shows that a sidewall spacer 18 is formed  
on each side wall of the gate 14 by, for example, depositing  
a layer of oxide and then etching back by plasma etching.

Finally, as is shown in FIG. 1d, further impurities (N or  
P type) are implanted to form heavily-doped regions 162 (N<sup>+</sup>  
or P<sup>+</sup> implantation regions). Due to the fact that sidewalls 18  
obstruct the impurities from entering into the lightly-doped  
regions 160 during this second implantation process, the  
implantation concentration in the regions 160 of drain and  
source 16 remain relatively light as compared to that in  
regions 162.

Two implantation procedures, however, in addition to the  
use of conventional photoresist and etching procedures, are  
required in the above exemplified fabrication procedure,  
which procedure is typically employed in the prior art. This  
relatively complicated fabrication procedure is not suitable  
for the efficient and cost-effective mass production of IC  
devices.

### SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide  
a fabrication process for forming lightly-doped drain and

source regions on the substrate of a semiconductor device  
having a gate.

It is another object of the present invention to provide a  
fabrication process for forming source and drain on the  
substrate of the semiconductor device each having both  
lightly- and heavily-doped regions.

It is still another object of the invention to provide a  
fabrication process for forming source and drain on the  
substrate of the semiconductor device having both lightly-  
and heavily-doped regions in only one implantation proce-  
dure.

### BRIEF DESCRIPTION OF THE DRAWING

Other objects, features and advantages of the present  
invention will become apparent by way of the following  
detailed description of the preferred but non-limiting  
embodiment, with reference to the accompanied drawings,  
wherein:

FIGS. 1a-1d show, in cross section, a semiconductor  
device at various process stages based on a prior art fabri-  
cation procedure; and

FIGS. 2a-2c show, in cross section, a semiconductor  
device at various process stages based on the fabrication  
procedure in accordance with the preferred embodiment of  
the present invention.

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIGS. 2a-2c depict a semiconductor device made in  
accordance with a preferred embodiment of the present  
invention is shown in cross section at various stages of  
fabrication.

#### Step 1

Referring first to FIG. 2a, on the P- or N-type semicon-  
ductor substrate 2, a field region oxide layer 20 is formed to  
define an active region 22. A gate oxide layer 240 and a  
polysilicon layer 242 are then formed on area 22 to define a  
gate 24. This process step is basically the same as that of the  
prior art, if comparison is made to the cross section shown  
in FIG. 1a.

#### Step 2

Turning to FIG. 2b, sidewall spacers 26 are then formed  
on the side walls of gate 24. The thickness of the sidewall  
spacers 26, as measured in a direction normal to the sub-  
strate 2 is smaller than the thickness of the sidewall spacer  
18 in the prior art device as shown in FIG. 1c. As can be seen  
from FIG. 2b, this thickness is also less than that of gate 24.  
The use of this smaller thickness allows partial passage of  
the implantation impurities into the substrate during a later  
implantation procedure to form a lightly-doped implantation  
region, as will be described in detail below.

To make the spacers 26, a layer of oxide, nitride, or  
polysilicon is deposited first, and then plasma etching is  
utilized to define the shapes of the sidewall spacers 26, so  
that the spacers 26 have a typical thickness (normal to the  
substrate 2) of about 500-2,500 Å. The thickness of the gate  
24 is usually about 4000 Å. Thus the thickness of the  
sidewall spacers 26 are less than the thickness of gate 24  
adjacent which they are disposed. The sidewall spacers 26  
are preferably made of a material selected from nitride and  
polysilicon, so as to avoid damaging the substrate 2 when  
plasma etching is used.



## 3

## Step 3

Referring now to FIG. 2c, at this stage, impurities (of N- or P-type) are implanted into the substrate 2 to form heavily-doped regions 280 (N<sup>+</sup> or P<sup>+</sup> doped). N-type impurities are preferably implanted into a P-type substrate 2 while P-type impurities are preferably implanted into a N-type substrate 2. Due to partial obstruction of implantation of the impurities by the presence of the spacers 26, the regions 282 underneath the spacers will be lightly-doped (N- or P-doped) compared with the other regions, namely regions 280, which are not obstructed by the spacers 26 during the implantation process. The gate 24 is sufficiently thick to block this implantation, while the spacers 26 are only sufficiently thick to obstruct, but not block, this implantation. The heavily-doped regions 280 and lightly-doped regions 282 together constitute the drain and source regions 28.

Thus, the present invention achieves the formation of a drain and a source on the semiconductor substrate with both lightly- and heavily-doped regions of type which are required for sub-micron fabrication of semiconductor integrated circuit devices. Moreover, the lightly- and heavily-doped regions are formed in one single implantation step, which simplifies the over fabrication procedure, as well as achieving reduced production costs.

Having described the invention in connection with a preferred embodiment, modification may now suggest itself to those skilled in the art. Thus the invention is not to be limited to the disclosed embodiment, except as required by the appended claims.

We claim:

1. A process for fabricating a semiconductor device having an active region and having a gate structure formed on a substrate, said gate structure having a gate thickness, said process comprising the steps of:

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forming a sidewall spacer on at least one sidewall of said gate structure by depositing a single insulating layer over the substrate and the gate structure and etching back the insulating layer to form the sidewall spacer, said sidewall spacer having a sidewall spacer thickness measured in a depth direction of said substrate such that an impurity implantation applied to said sidewall spacer is only obstructed but not blocked by said sidewall spacer thickness, said sidewall spacer thickness being less than said gate thickness; and

implanting impurities to form at least one lightly-doped region underneath said sidewall spacer while at the same time forming at least one heavily-doped region in the area not obstructed by said sidewall spacer, said at least one lightly-doped region being adjacent to said at least one heavily-doped region and defining with the adjacent heavily-doped region said active region of said semiconductor device.

2. The process of claim 1, wherein said sidewall spacer is a nitride spacer.

3. The process of claim 2, wherein said sidewall spacer thickness is in the range of 500–2,500Å.

4. The process of claim 1, wherein said sidewall spacer is an oxide spacer.

5. The process of claim 4, wherein said sidewall spacer thickness is in the range of 500–2,500Å.

6. The process of claim 1, wherein said sidewall spacer is a polysilicon spacer.

7. The process of claim 6, wherein said sidewall spacer thickness is in the range of 500–2,500Å.

8. The process of claim 1, wherein said active region defines a source region.

9. The process of claim 1, wherein said active region defines a drain region.

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